Stopping power of electron gas


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The polarizational stopping power of heavy ions in fully ionized plasmas is described by the Lindhard formula [1]:

\[
\left[ \frac{dE}{dx} \right]_{\text{pol}} = 2 \left( \frac{Z_p e^2}{\pi v^2} \right) \int_0^\infty \int_0^k \omega^2 \left( -\text{Im} \left[ \frac{\varepsilon^{-1}(k, \omega)}{\omega} \right] \right) d\omega,
\]

whose high-velocity asymptotic form was found by Bohr, Bethe, and Larkin [2]:

\[
\left[ \frac{dE}{dx} \right]_{\text{pol}} \approx \left( \frac{Z_p e^2}{v} \right)^2 \ln \left( \frac{2m_e v^2}{\hbar \omega_p} \right).
\]

The plasma inverse dielectric function (IDF), \( \varepsilon^{-1}(k, \omega) \), was determined in [3] within the moment approach [4], complemented by some physical observations in terms of two characteristic frequencies \( \omega_1 \) and \( \omega_2 \), which are the ratios of the frequency power moments of the IDF imaginary part, in the following form:

\[
\varepsilon^{-1}(k, \omega) = 1 + \frac{\omega_1^2 \left( \sqrt{2} \omega_1 \omega + i \omega_2^2 \right)}{\sqrt{2} \omega_1 \omega (\omega^2 - \omega_2^2) + i \omega_2^2 \left( \omega^2 - \omega_1^2 \right)}.
\]

The frequencies \( \omega_1 \) and \( \omega_2 \) can be rigorously evaluated using the static structure factor (SSF) of the system. Nevertheless, here we employ the following interpolating expressions [5,6]:

\[
\omega_1^2 = \omega_1^2(k) = \omega_p^2 \left( 1 + k^2 k_0^2 + k^4 k_s^4 \right), \quad \omega_2^2 = \omega_2^2(k) = \omega_p^2 \left( 1 + \left( \frac{v_m^2 k^2}{\omega_p^2} - \frac{v_m^2 k_s^2}{\omega_p^2} \right) \right).
\]

The interpolation and fitting parameters introduced are chosen as follows:

\[
v_{\text{int}}^2 = -4 \frac{\Gamma^{3/2}}{15} \frac{0.9052}{\beta m_e} \left( \frac{0.27243}{1 + \Gamma} \right), \quad \Gamma = \frac{\beta e^2}{a}, \quad k_s^2 = 12 r_s / a_s^4, \quad r_s = a / a_s,
\]

\( a \) and \( a_s \) are the Wigner-Seitz and Bohr radii, respectively; \( \beta = 1 / (k_B T) \), \( k_D^{-1} \) is the Debye radius, \( k_s \) stands for the Boltzmann constant with \( T \) being the plasma temperature.

The numerical results obtained for the energy losses of heavy ions moving in an electron gas are found in good agreement with the PIC simulation data [7].

REFERENCES